SEDIMENT TRANSPORT HISTORY ON THE NORTHERN CALIFORNIA SHELF AND SLOPE: INFERENCES FROM ACOUSTIC SIGNATURES

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LONG TERM GOALS

A unifying concept of the STRATAFORM Project is that sediment accumulates on the shelf and slope in predictable patterns. Further, these patterns are controlled by water depth, sediment sources, and the principal styles of transport and deposition. One of the major goals of the over-all project is to gain a better understanding of how strata form and how they combine to form characteristic stratigraphic sequences, such as drapes, aprons, wedges, sigmoids, and other characteristic geometries. An essential part of this understanding is the analysis and interpretation of surface features and deposits in the upper 50 m of the shelf and slope to provide information on the mechanism of sediment transport and deposition. Interpreting the signatures of various processes in surface and near surface deposits provides a critical link between knowledge gained from measuring physical processes that are dominant over time spans from the duration of a single event to several years, and those inferred from seismic-reflection data that may represent 10^2 to 10^4 years.

SCIENTIFIC OBJECTIVES

Our objectives are to identify the types of sediment signatures that occur in high-resolution seismic-reflection and sidescan-sonar records from the California continental margin, correlate them with the causative process (flood sedimentation, turbidity flow, slow hemipelagic drape, slope currents, etc.) that formed the deposits, and identify the relative abundance and significance of slope- and shelf- sediment signatures. These signatures can then be correlated with results from other STRATAFORM investigations and major patterns can be related to fluctuating sediment sources, sea level, and climate.

Our specific objectives for FY1997 included the following:

- Complete image processing and preliminary interpretations of high-resolution seismic-reflection and sidescan-sonar data collected in the California STRATAFORM site in 1996.

- Conduct office studies of high resolution acoustic and sidescan sonar images to specifically identify:
  - continuity, extent, vertical history, and overall significance of gullies on the slope
  - critical evidence to document the timing and sedimentary processes that formed the Humboldt Slide Zone;
  - sediment sequences on the shallow shelf that document the styles of sedimentation and the amount of sediment deposited during the last transgression and still stand of sealevel
  - the nature and style of sediment deformation in the vicinity of a large, active anticline on the outer shelf;

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- the relationship between subsurface gas and surface pock marks.

- Participate in a ROV cruise with the Monterey Bay Aquarium Research Institute to identify and sample pock marks, gullies, and slide blocks.

- Present preliminary findings at national meetings and workshops on slope gully systems, slope sediment-gravity deposits, reflector geometry, and inferred sediment processes, including mass failure, gully formation, turbidity flows, and aggradation and progradation of the shelf-slope sediment sequences.

BACKGROUND

Sediment is deposited on shelves and slopes in distinctive packages or sequences that bear similarities at many sites around the world. The exact processes that form these sequences are not well understood. The STRATAFORM project seeks to integrate studies of sediment transport with observations of sediment deposition and with computer models to develop a better understanding of how sediment sequences originate on continental margins.

This study contributes to an integral part of STRATAFORM, the investigation of small-scale topography on the shelf and slope surface. High-resolution seismic-reflection data and sidescan sonar are employed to document the presence and distinctive characteristics of marine sediment-gravity deposits and record the diagnostic geometric patterns of shallow subsurface strata on the shelf and slope.

Key scientific issues were identified from analysis of high-resolution acoustic profiles and sidescan data from two major research cruises using the Huntec DTS System and a Datasonics SIS-1000. Our research focus has been directed toward the following science topics, all of them key to addressing the over-arching goals of the project and the STRATAFORM Program:

1. The role of channels in slope evolution: how they transport and distribute sediment across the slope and onto the plateau.

2. Detailed analysis of the Humboldt slide zone: what is the dominant style of sediment mass-transport (slide vs. flow).

3. Stratigraphy of the inner shelf: separation of units above the transgressive surface of erosion into transgressive and high-stand components, and mapping the loci of deposition and total volumes and over-all rates of sedimentation.

4. Mapping of surface pock marks and subsurface gas: how the two are related in distribution and genesis.

5. Tectonic deformation of shelf and slope strata: uplift on an upper slope anticline has resulted in large waves of near-surface sedimentary strata, and the causative processes need to be delineated.

ACCOMPLISHMENTS AND RESULTS

<u>Humboldt Slide</u>

The three-dimensional architecture of Humboldt Slide Zone, located on the northern California continental slope, has been imaged by a combination of multibeam bathymetry, Huntec Deep-Tow seismic profiling, and sidescan sonar. The failure is late Pleistocene to early Holocene in age and was promoted by a combination of factors. The immediate area is a local depocenter with high sedimentation rates of organic-rich sediment, there has been local steepening of slopes by tectonic uplift, and the entire area is one of high seismicity. The slide represents a retrogressive, shear-dominated, minimum-movement failure that appears to have occurred as a sequence of events, first by subsidence extension of the middle of the feature, followed by upslope retrogressive failure and downslope compression, then by translational sliding at the top of the

slide. Rapid degassing, as evidenced by abundant pock-marks, may have inhibited downslope translation. The slide may still be active because a Holocene hemipelagic drape is offset by some of the shear surfaces. Crown cracks occur above the present head of the failure and may represent the next generation of failure.

Slope Gully System

Our high-resolution seismic and sidescan-sonar surveys off northern California, combined with the STRATAFORM multibeam bathymetry and backscatter survey provide a new basis for evaluating gully morphology, distribution, and significance to slope sedimentation and evolution. The continental margin off northern California contains a set of straight, evenly spaced, and parallel to subparallel gullies that begin at the 350 m isobath and extend onto the Eel and Klamath plateaus and into Trinity Canyon. The surface gullies are typically 200-m wide and only 1-to 2-m deep. The gullied slope, best developed along a 20-km stretch off the Mad River, is underlain by a sedimentary sequence that contains abundant buried gullies to subsurface depths of over 150 m. Although some of the buried gullies are distinctly erosional, most are part of the aggradational pattern responsible for the over-all growth of the slope. The latest phase of gully erosion is within 20 m of the seafloor. Erosional gullies locally truncate individual reflectors, have small depositional levees, and exhibit greater relief than do gullies on the surface of the seafloor. The cycles of downcutting and gully excavation are a minor part of the stratigraphic section, and are likely related to the combined results of lower sealevels and higher sediment yields.

Shelf Sedimentation

Studies of shelf-to-slope strata and reflector packages indicate that the high sediment delivery rates common to the northern California margin at present persisted through much of the Holocene. Whereas specific rates are not yet available for specific time periods within the Holocene, it is clear that large volumes of sediment emanated from the Eel River source region. Transgressive deposits overlie thick low-stand deposits on the shelf and slope, and extend onto the shelf where they are capped by high-stand deposits. In total, the Holocene shelf sequences are about 20 m thick, and their geometry is markedly controlled by the ongoing structural evolution of the shelf that provides sediment pathways, depocenters, and barriers.

SCIENTIFIC IMPACT

Our studies thus far have provided new information about shelf and slope sedimentation. Our preliminary results demonstrate that sequence stratigraphic concepts operate differently on the narrow, high-relief, high-sediment load areas characteristic of Pacific-style margins. Changes in base level seem to be quickly accommodated, although sedimentation remains more-or-less continuous, with only subtle changes associated with shifts in sealevel. Thus, the transgressive tract appears to be relatively thick and dominated by shelf deposition, in contrast to the coastal-plain sequences where transgressive facies are relatively rare or dominated by estuarine deposits.

The slope has long been held to be a zone of by-passing, sediment mass failure, or sediment deposition by surface fall-out and draping. Our results show that small channels, or gullies, are pervasive at distinct periods of slope history. The gullies are straight, relatively narrow (<100 m wide), shallow (1 to 2 m deep) and uniform in spacing (average about 400 m apart) between 350 m and 600 m water depth. They merge downslope to form a series of deep channels that funnel sediment gravity flows onto the slope and base-of-slope environments. Prior to multibeam mapping, the presence of small gullies such as these were difficult to interpret because of their small scale. The presence of the gullies in the subsurface suggests a strong link to sediment accumulation patterns and slope aggradation. The subsurface data indicate that periods of active gully transport (downcutting and levee growth) are followed by periods of pervasive sediment drape that mimics the relict topography and maintains the gully shape. Under conditions similar to those at present, gullies are either maintained or infilled by a combination of dispersive sediment drape and downslope sediment gravity flows. If the gullies represent conduits of sediment-gravity flows, then these flows may rival large mass failures as a major mechanism of slope transport and may be a dominant mechanism at certain times for slope aggradation and progradation--a significant change in our understanding of sequence evolution on slopes.

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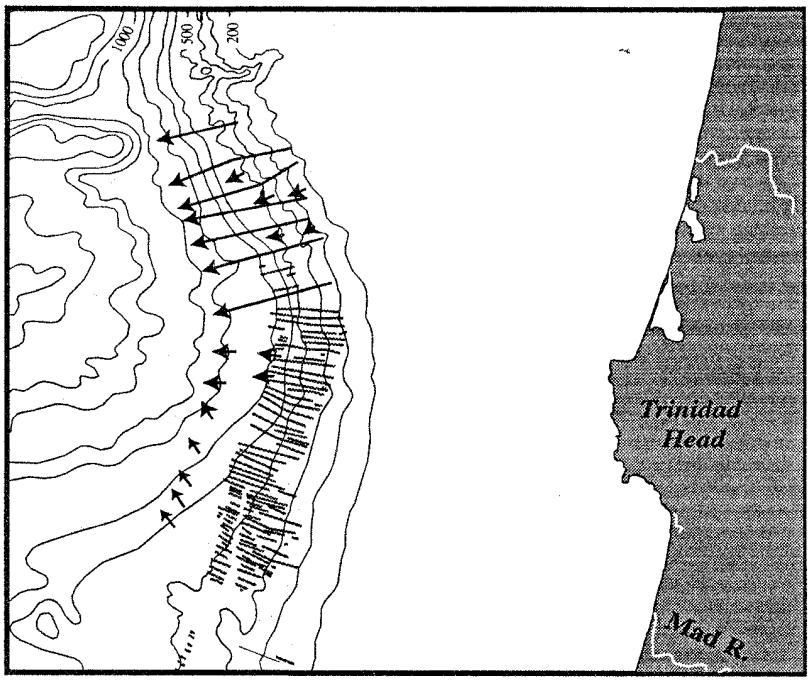

Figure 1. Map showing the distribution of gullies and channels off Trinidad Head, northern California. Straight lines mark the location of each gully. Arrows are schematic representations of the location of the deeper, wider channels.

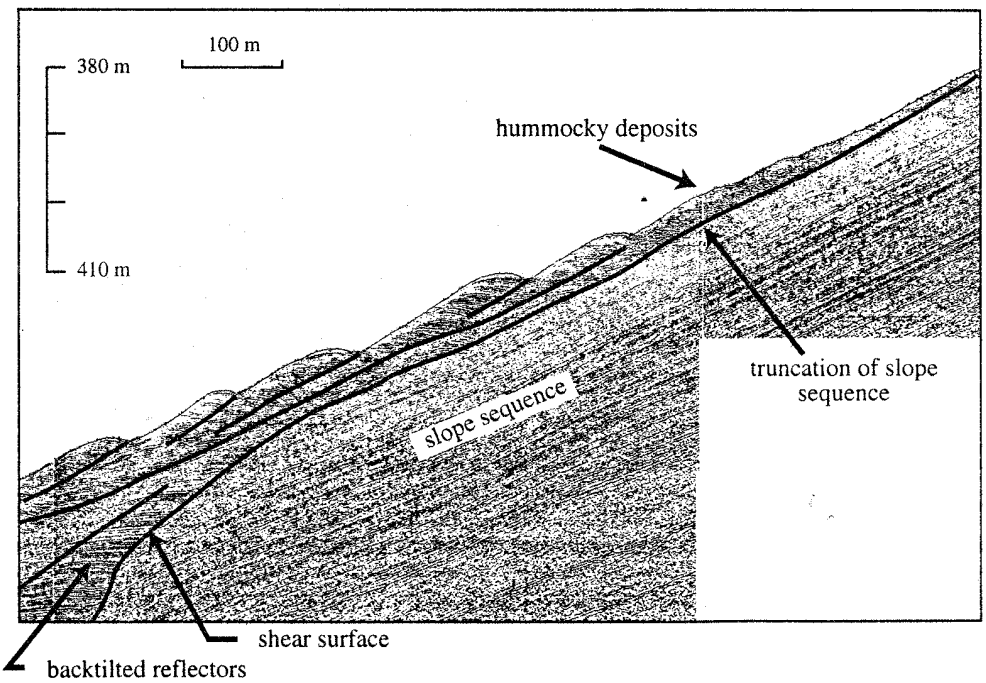

Figure 2. Huntec line showing upper portion of Humboldt Slide. Hummocky deposits bury the normal slope sequence. Shear surfaces separate sequences of reflectors. Vertical exaggeration 7X